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4. Title of the invention	TRANSPORT FORMAT COMBINATION SELECTION IN THE UPLINK FOR THE FLEXIBLE LAYER ONE
5. Name of your agent *(if you have one)*	Siemens Plc
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TRANSPORT FORMAT COMBINATION SELECTION IN THE UPLINK FOR THE FLEXIBLE LAYER ONE

GLOSSARY OF ABBREVIATIONS USED

(E)GPRS	(Enhanced) General Packet Radio Service
MS	Mobile Station
TBF	Temporary Block Flow
USF	Uplink State Flag
GERAN	GSM/EDGE Radio Access Network
TFCI	Transport Format Combination Indicator
UTRAN	Universal Terrestrial Radio Access Network
UE	User Equipment
3GPP	Third Generation Partnership Project
TTI	Transmission Timing Interval
MAC	Medium Access Control/Message Authentication Code
CDMA	Code Division Multiple Access
TDMA	Time Division Multiple Access
UL	Uplink (Reverse Link)
RXLEV	Received Signal Level
BEP	Bit Error Probability
BLER	Block Error Ratio
BSS	Broadband Switching Service
SACCH	Slow Access Control Channel
RLC	Radio Link Control
BTS	Base Transceiver Station
TP	Third Party
VoIP	Voice over Internet Protocol
TrCH	Transport Channel
TS	Technical Specification
EDGE	Enhanced Data rates for GSM Evolution
GSM	Global System for Mobile Communications

1 Introduction

In (E)GPRS, when the MS has more than one TBF active, the scheduling of which TBFs should transmit in the uplink is under the control of the network: the network decides which TBF should be transmitted in the next block allocated to the user, and signals this to the MS by means of the USF[i]. The MS has the option to preempt a TBF scheduled for transmission if in the mean time a TBF with higher priority has become active. This is made possible by the fact that, in (E)GPRS, only one TBF can be transmitted in a radio block.

With the introduction of the Flexible Layer One (FLO) in the GERAN, on the other hand, it will be possible to multiplex data belonging to different logical channels in the same radio packet. A transport format combination (TFC) could contain transport blocks from several transport channels, which could be linked to different logical channels, thus allowing the possibility to multiplex different services – possibly with different quality of service requirements – in the same radio packet. For example, it may be possible to multiplex conversational services and interactive services in the same radio packet. Therefore, the scheduling of different uplink traffic flows, possibly with different priorities, from the same MS by means of the USF is not feasible. First of all, in order to signal to the MS what data should be sent, the network should not send a USF but a TFCI, so the signalling would need to be changed[ii]. Additionally, the network has no knowledge of which logical channels have data available to send, and this makes the selection of a particular TFC unfeasible. Therefore, the MS should play a role in the scheduling of data in the uplink.

The present invention addresses the requirement for the mobile station to schedule traffic in the uplink. However, in selecting the particular TFC to be used in the uplink, the conditions of the radio channels should be taken into account. Since the channel conditions in the UL are not known to the MS, but only to the network, it is desirable to allow the network to retain some control on the procedure in order to take the radio conditions into account. This has hitherto not been possible for the following reasons.

The current assumption is that the network has full control of what data the mobile transmits in the uplink. With the introduction of the Flexible Layer One, the network has not enough information to make a decision. Therefore, the mobile station should get involved in making a decision.

The present invention addresses this requirement by providing, in a mobile telephone system, have a method for the selection of the TFC which is under the control of the mobile station, but at the same time is "network-assisted": the network informs the MS about which set of TFCs can be transmitted based on the current conditions of the radio channel; the MS then selects the particular TFC to used according criteria like the priority of the data to be transmitted.

A proposal for a scheme to be used with FLO in the GERAN is presented.

2 Summary of the UTRAN algorithm

In the UTRAN, the scheduling of uplink data is under the control of the mobile station. A set of criteria for the "TFC selection in UE" are defined; they are specified in:

- 3GPP TS 25.133 [1], clause 6.4 (see Annex B)
- 3GPP TS 25.321 [2], clause 11.4 (see Annex A)
- 3GPP TS 25.331 [3], clause 8.6.5

The following is a brief summary of the steps followed by the UE to select the TFC to use in each radio block.

1. According to 3GPP TS 25.321, a given TFC can be in one of three possible states:

- Supported state
- Excess-power state
- Blocked state

2. The criteria to move from one state to the others are evaluated based on the *estimated UE transmit power*[iii] of a given TFC, and are given in 3GPP TS 25.133 (see Annex B). These criteria are evaluated at least once every radio frame (10 ms).

3. A "minimum set" of TFCs is defined[iv], as specified in 3GPP TS 25.331; the TFCs that belong to the minimum set will never be in the Blocked state.

4. The UE then determines the set of "valid" TFCs, according to the rules specified in 3GPP TS 25.321 (see Annex A); one of these rules, for example, is that a "valid" TFC must not to be in the Blocked state. This is done at every boundary of the shortest TTI.

5. The chosen TFC is then selected from the set of valid TFCs according to specified criteria, mainly based on the priority of the data available to be sent[v] and the amount of data that would be sent using a particular TFC. These criteria are given in 3GPP TS 25.321 (see Annex A). The selection is made by the MAC layer in the UE.

Unfortunately, a scheme similar to the one used in the UTRAN could not be used in the GERAN, because a criterion based on the estimated UE transmit power is suitable for a CDMA system but would not work in a TDMA system[vi]. Therefore, in the GERAN, different criteria need to be defined for the MS to decide whether a TFC is "supported" or not.

One criterion could be based on the radio channel conditions (e.g. C/I). The problem is that the channel conditions in the UL are not known to the MS, but only to the network.

3 Proposed algorithm for the GERAN (Summary of the invention)

In order to address the issues raised in the previous section, we propose the use of an algorithm called Network-assisted Uplink TFC Selection (NUTS). A basic description of the algorithm follows.

1. TFCs are ranked according to the radio conditions or signal quality required to achieved a specified quality of service[vii] , for example the higher the TFCI, the better the

quality of the radio link required. This could be characterised, for example, in terms of RXLEV, BEP, the BLER on the different transport channels, or other parameters.

2. The ranking is communicated to the MS by means of the order in which they are signalled in the assignment message: the TFCs are signalled in the assignment message in increasing order of quality of the link required.

3. Based on the measurement performed by the BSS, the network determines the highest TFCI that, with the current radio conditions, would meet the quality of service criteria.

4. The network sends in the downlink (e.g. on the SACCH) the indication of such TFCI.

5. The MS "should" use only TFCs whose TFCI is lower than the TFCI indicated by the network. The MS selects the particular TFC to be used for transmission, for example according to the priority of the data to be transmitted.

In practice, the network signals to the MS which TFCs are available based on the current radio channel conditions and signal quality; the MS then selects the actual TFC to be used for transmission in the next frame according to the priority of the data to be sent. In order to have consistent behaviour from all mobiles, the rules for uplink scheduling should be standardised. This is the approach taken in the UTRAN, and should be followed in the GERAN as well. The fact that the rules are standardised will also help during the testing phase, because in the same scenario it could be expected that the behaviour of terminals from different manufacturers will be the same.

As an example, let's consider the case in which 10 TFCs are defined in the TFCS, and the network signals that TFC#6 is the highest TFC that the MS is allowed to use. Then the MS is allowed to select only TFC#1 to TFC#6 (the set outlined in grey in Figure 1). The selection will be made by the MAC layer, according to rules and criteria that will be standardised.

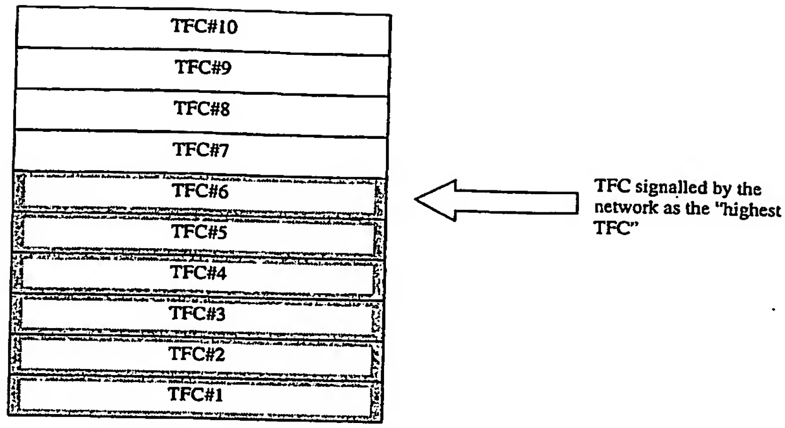

Figure 1

Note that this is only a general description of the algorithm, and a detailed description will require further investigation. For example, the criteria used by the MS to choose the TFC within the set of valid TFCs are for further study. Examples of these criteria could the following:

- RLC/MAC control messages will always have the highest priority
- services which are assigned a higher priority (e.g. conversational services) are transmitted before services with a lower priority
- retransmissions have higher priority than new transmissions
- etc.

The algorithm will require the definition of a function that analyses the measurements performed by the BTS (RXLEV, BEP, BLERs, etc.) and determines the "highest TFC". It is likely that this function will be located in the MAC in the BSS. Note that a similar function would be required in the BSS for the selection of the TFC to be used in the downlink; in this case, the selection will take into account the measurement reports that are sent by the MS.

4 Signalling on the SACCH

There are two possible methods for the network to signal the "highest TFCI" to the MS: one is to use inband signalling, the other one is to use the SACCH associated with the

dedicated traffic channel. Using inband signalling has the advantage that a new value of the "highest TFCI" could be signalled to the MS every 20 ms, and therefore the adaptation to the channel conditions is very fast. The disadvantage is that signalling it in each radio packet will consume resources and will lead to a degradation of performance (e.g. a higher C/I will be required in order for the other transport blocks to achieve the same BLER).

In a SACCH message, only 2 spare bits are currently available, whereas signalling a TFCI would require 5 bits. Therefore it is not possible to signal the "highest TFCI" in a SACCH message. One alternative would be to use the SACCH/TP, similarly to what is done for EPC, but instead of having the EPCCH associated with it, send in parallel a new channel, which is used to signal the TFCI. Since 12 bits are available in each SACCH/TP burst, and the transmission of a TFCI requires 36 bits (when coded), it would take three SACCH bursts to signal a TFCI. There are two alternatives:

1) a new value of the TFCI is sent every three SACCH bursts, i.e. every 360 ms
2) a new value of the TFCI is sent every four SACCH bursts (480 ms), in order to align with a SACCH block period

The major problem is the delay for the BTS to perform the measurements and for the network to signal the 'highest TFCI' to the MS (will depend on the particular scheme used to signal it); an adaptation rate of 360 ms may be too slow, and if the channel conditions vary rapidly, the performance of this procedure may not be very good. System level simulations would be needed to assess the performance of this scheme (or any other alternative ones).

Another possible option would be, instead of signalling the "highest TFC" that the MS can use (i.e. an absolute value), signal whether the "highest TFCI" should shift up or down with respect to the current value held by the MS (similarly to what is done for the AMR). This could be done every SACCH burst (120 ms), by using the 12 bits that are not used by the SACCH/TP. The advantage of this is that the adaptation to the channel is faster, however the "highest TFC" can be varied in smaller steps. This option would also be more suitable for inband signalling.

5 Conclusions

With FLO, the scheduling of different uplink traffic flows (with different priorities) from the same MS by means of the USF is not feasible. The present invention provides an algorithm that allows the MS, with the assistance of the network, to select the TFC to be used in the uplink. This is only an initial proposal, and a detailed definition will require further investigation.

It is for further study how rate adaptation can be performed in the case of VoIP or other conversational services, which require a higher adaptation rate. Also, the interactions with the proposed algorithm will require further investigation.

6 References

[1] 3GPP TS 25.133 "Requirements for Support of Radio Resource Management (FDD)"

[2] 3GPP TS 25.321 "MAC protocol specification"

[3] 3GPP TS 25.331 "Radio Resource Control (RRC); Protocol Specification"

[4] G2-030113 "TR 45.902 on Flexible Layer One v0.4.0", GERAN2#12bis, Saint Paul de Vence (France), 13-17 January 2003

7 Notes

i. In Release 99 and Release 4, every mobile can only have one TBF allocated, and therefore the USF is used to schedule transmission from different mobiles multiplexed on the same PDCH. With the inclusion in the specifications of the Multiple TBF feature in Release 5, the USF can be used also to schedule different TBF belonging to the same MS.

ii. Note that, since FLO is only used on dedicated channels, the USF is no longer needed to schedule transmission in the uplink from different mobiles; therefore, it has been proposed to remove the USF from the RLC/MAC header.

iii. 3GPP TS 25.133 specifies that: "The UE transmit power estimation for a given TFC shall be made using the UE transmitted power measured over the measurement period, defined [...] as one slot, and the gain factors of the corresponding TFC."

iv. In the uplink TFCS, the minimum set of TFCs is the set of TFCs that is needed for the TFC selection algorithm defined in 3GPP TS 25.321 to give a predictable result.

v. Every logical channel is assigned a priority from 1 to 8.

vi. In a CDMA system, power is the common shared resource. The (closed-loop) power control algorithm is used to limit the amount of power transmitted by each mobile to the minimum required: the power transmitted by the mobile is continuously adjusted so that the power received by the base station is (approximately) constant. The target received power is set to a value such that, for example, the BLER for the data transmitted is lower than a certain threshold. As the channel conditions vary, the power transmitted by the mobile will vary as well. The rate of adaptation is very fast, much faster than in the GERAN (1500 times a second in the UTRAN, instead of about two times a second of the standard GSM power control algorithm). Therefore it is not possible to rely on the GERAN power control algorithm

vii. For example, the requirement could be that, with the current radio conditions, the transport blocks sent on all the TrCHs included in the TFC are received with a BLER lower than a specified value (e.g. 1%).

Annex A – Excerpt from 3GPP TS 25.321

11.4 Transport format combination selection in UE

RRC can control the scheduling of uplink data by giving each logical channel a priority between 1 and 8, where 1 is the highest priority and 8 the lowest. TFC selection in the UE shall be done in accordance with the priorities indicated by RRC. Logical channels have absolute priority, i.e. the UE shall maximise the transmission of higher priority data.

If the uplink TFCS configured by UTRAN follows the guidelines described in [25.331] the UE shall perform the TFC selection according to the rules specified below. If these guidelines are not followed then the UE behaviour is not specified.

The UE shall continuously monitor the state for each TFC based on its required transmit power versus the maximum UE transmit power. A given TFC can be in any of the following states:

- Supported state;
- Excess-power state;
- Blocked state.

The following diagram illustrates the state transitions for the state of a given TFC:

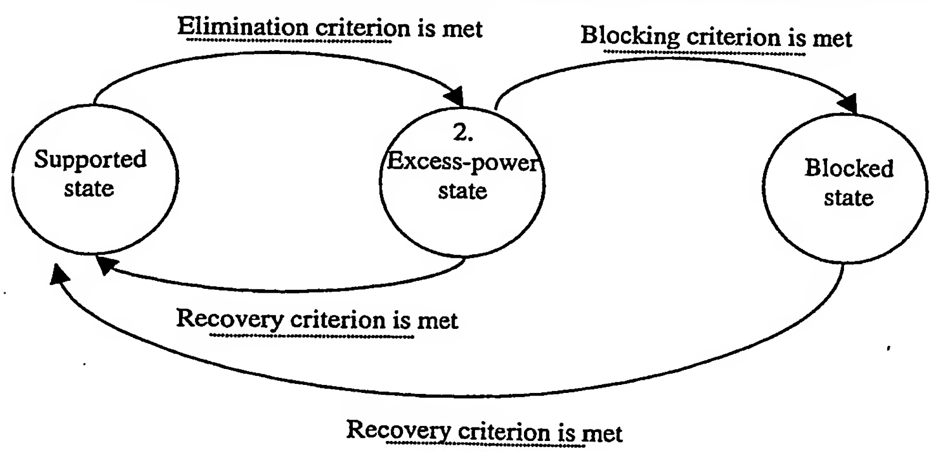

Figure 11.4.1: State transitions for the state of a given TFC

The state transition criteria and the associated requirements are described in [25.133, 25.123]. The UE shall consider that the Blocking criterion is never met for TFCs included in the minimum set of TFCs (see [25.331]).

Every time the set of supported TFCs changes, the available bitrate shall be indicated to upper layers for each logical channel in order to facilitate the adaptation of codec data

rates when codecs supporting variable-rate operation are used. The details of the computation of the available bitrate and the interaction with the application layer are not further specified.

Before selecting a TFC, i.e. at every boundary of the shortest TTI, the set of valid TFCs shall be established. All TFCs in the set of valid TFCs shall:

1. belong to the TFCS.
2. not be in the Blocked state.
3. be compatible with the RLC configuration.
4. not require RLC to produce padding PDUs (see [25.322] for definition).
5. not carry more bits than can be transmitted in a TTI (e.g. when compressed mode by higher layer scheduling is used and the presence of compressed frames reduces the number of bits that can be transmitted in a TTI using the Minimum SF configured).

The UE may remove from the set of valid TFCs, TFCs in Excess-power state in order to maintain the quality of service for sensitive applications (e.g. speech). Additionally, if compressed frames are present within the longest configured TTI to which the next transmission belongs, the UE may remove TFCs from the set of valid TFCs in order to account for the higher power requirements.

The chosen TFC shall be selected from within the set of valid TFCs and shall satisfy the following criteria in the order in which they are listed below:

1. No other TFC shall allow the transmission of more highest priority data than the chosen TFC.
2. No other TFC shall allow the transmission of more data from the next lower priority logical channels. Apply this criterion recursively for the remaining priority levels.
3. No other TFC shall have a lower bit rate than the chosen TFC.

The above rules for TFC selection in the UE shall apply to DCH, and the same rules shall apply for TF selection on RACH and CPCH.

Annex B – Excerpt from 3GPP TS 25.133

6.4 Transport format combination selection in UE

6.4.1 Introduction

When the UE estimates that a certain TFC would require more power than the maximum transmit power, it shall limit the usage of transport format combinations for the assigned transport format set, according to the functionality specified in section 11.4 in [25.321]. This in order to make it possible for the network operator to maximise the coverage. Transport format combination selection is described in section 11.4 of [25.321].

6.4.2 Requirements

The UE shall continuously evaluate based on the Elimination, Recovery and Blocking criteria defined below, how TFCs on an uplink DPDCH can be used for the purpose of TFC selection. The evaluation shall be performed for every TFC in the TFCS using the estimated UE transmit power of a given TFC. The UE transmit power estimation for a given TFC shall be made using the UE transmitted power measured over the measurement period, defined in 9.1.6.1 as one slot, and the gain factors of the corresponding TFC.

The UE shall consider the Elimination criterion for a given TFC to be detected if the estimated UE transmit power needed for this TFC is greater than the Maximum UE transmitter power for at least X out of the last Y successive measurement periods immediately preceding evaluation. The MAC in the UE shall consider that the TFC is in Excess-Power state for the purpose of TFC selection.

MAC in the UE shall indicate the available bit rate for each logical channel to upper layers within T_{notify} from the moment the *Elimination* criterion was detected.

The UE shall consider the *Recovery* criterion for a given TFC to be detected if the estimated UE transmit power needed for this TFC has not been greater than the Maximum UE transmitter power for the last Z successive measurement periods immediately preceding evaluation. The MAC in the UE shall consider that the TFC is in Supported state for the purpose of TFC selection.

MAC in the UE shall indicate the available bitrate for each logical channel to upper layers within T_{notify} from the moment the *Recovery* criterion was detected.

The evaluation of the *Elimination* criterion and the *Recovery* criterion shall be performed at least once per radio frame.

The definitions of the parameters X,Y and Z which shall be used when evaluating the *Elimination* and the *Recovery* criteria when no compressed mode patterns are activated are given in Table 6.0.

Table 6.0: X, Y, Z parameters for TFC selection

X	Y	Z
15	30	30

The UE shall consider the *Blocking* criterion for a given TFC to be fulfilled at the latest at the start of the longest uplink TTI after the moment at which the TFC will have been in Excess-Power state for a duration of:

$$(T_{notify} + T_{modify} + T_{L1\_proc})$$

where:

T_{notify} equals 15 ms

T_{modify} equals $MAX(T_{adapt\_max}, T_{TTI})$

$T_{L1\ proc}$ equals 15 ms

T_{adapt_max} equals $MAX(T_{adapt\_1}, T_{adapt\_2}, \ldots, T_{adapt\_N})$

N equals the number of logical channels that need to change rate

T_{adapt_n} equals the time it takes for higher layers to provide data to MAC in a new supported bitrate, for logical channel n. Table 6.1 defines T_{adapt} times for different services. For services where no codec is used T_{adapt} shall be considered to be equal to 0 ms.

Table 6.1: T_{adapt}

Service	T_{adapt} [ms]
UMTS AMR	40
UMTS AMR2	60

T_{TTI} equals the longest uplink TTI of the selected TFC (ms).

The Maximum UE transmitter power is defined as follows

Maximum UE transmitter power = MIN(Maximum allowed UL TX Power, UE maximum transmit power)

where

Maximum allowed UL TX Power is set by UTRAN and defined in [25.331], and

UE maximum transmit power is defined by the UE power class, and specified in [25.101].

CLAIMS:

1. In a mobile telephone network, a method for the selection of the TFC which is under the control of the mobile station, but at the same time is “network assisted”: the network informs the MS about which set of TFCs can be transmitted based on the current conditions of the radio channel; the MS then selects the particular TFC to used according criteria like the priority of the data to be transmitted

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